Elimination of ‘Ghost’-Effect-Related Systematics in the X-ray Optics Metrology with Long Trace Profiler

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The long trace profiler (LTP) is a basic metrology tool for highly accurate testing the figure of X-ray optics with slope variations on the order of one micro-radian rms. The LTP records the local slope profile of a surface by measuring the reflection angle of a laser probe beam as the beam is transported across the surface by an air bearing carriage. Beginning with the second generation LTP systems, a reference arm in addition to the probe arm is used to subtract the systematic errors related to laser pointing instability and carriage wiggling. The probe and the reference beams produce separate spatial patterns of interference fringes on corresponding position-sensitive detectors. The position of a pattern depends on reflection angle for the beam. Separation between the probe and reference patterns is a measure of the slope of the mirror surface at the point of measurement.

The origin of the ‘ghost’ effect is the cross-contamination of the probe and reference signals one into another. As the ‘ghost’ signal overlaps with the primary signal, the computed centroid of the pattern changes depending on the relative position of the ‘ghost’ leading to the systematic perturbation in the measured slope trace of about 1-2 μrad. The ‘ghost’ effect is significantly increased for a cylindrical or a twisted mirror, because the interference feature from the probe arm moves not only tangentially along the corresponding detector array, but also in the sagittal direction, spilling onto the detector for the reference arm lying parallel to it.

The main results of this work are a new improved LTP data acquisition technique, and special software developed to reduce this systematic effect. The idea is to separately measure the ‘ghost’ features in both arms and then subtract the ‘ghost’ intensities from the corresponding interference patterns. The procedure preserves the advantage of simultaneously measuring the probe and reference signals. A series of successive LTP intensity measurements with open and blocked beams are linearly combined with a specially developed program based on National Instruments LabVIEW software. The program constructs new probe and reference intensity files, which are then fitted with the usual LTP fitting procedure to find corrected slope values.

The effectiveness of the proposed method for minimizing the LTP systematic error due to the ‘ghost’ effect is illustrated with LTP metrology of a variety of X-ray mirrors.

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